FUTURE METEOROLOGICAL READOUT TERMINALS*

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ABSTRACT

Field terminal designs to readout satellite meteorological data are described for future applications. The development objectives include cost effective designs, easy transport and deployment, and increased resistance to interference. Three distinct classes of field terminals are discussed, and design descriptions are provided. Design features include an integrated antenna/receiver assembly and a laptop computer platform that can easily be transported. A design for S-band RDS service has been developed and demonstrated. A SBIR activity to develop/demonstrate the other two tactical antenna packages has been initiated. These two terminal designs will also provide technology transitions to the NPOESS LRD and HRD downlinks.

I. Introduction

Meteorological satellites provide timely data to worldwide users. The remote sensing capabilities of meteorological satellites have had continuous improvements, and future designs with significantly improved performance capabilities are being configured. Extensive development is underway with planned sensor demonstration and implementation and associated ground processing. Improved field terminal designs with additional performance and capabilities are also needed. Opportunities exist to integrate terminal antennas with inexpensive COTS ASIC receiver technology to obtain effective tactical equipment and today's significantly improved laptop computer platforms can support the terminal control and data processing and storage needs.

Three distinct classes of military field users exist. The first user class has modest requirements for meteorological data and high demands for simple, highly portable equipment to satisfy first-in tactical requirements. An example terminal for RDS reception, described elsewhere in this symposium (Ref. 1), illustrates the intent and objectives outlined here. The second user class requires selected imagery channels at the highest resolution providing more detailed data, and equipment, while still highly portable, that is more extensive than the first class. The capability to communicate to other satellites and receive broadcast data when remote sensing satellites are not in view increases the design utility and reduces the required equipment to transport, an attractive feature for tactical use. The third user class at the Operational Weather Squadron (OWS) requires all available data with the highest resolution to produce theater products for dissemination to Combat Weather Teams (CWT) in the field. The third user class has reduced demands for portability but requires cost-effective equipment with little susceptibility to interference. These three classes of military field users have significantly different requirements for their equipment.

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Effective equipment development for the three user classes has several implications. The satellite transmission has a clear impact on the requirements for user terminals. Design attention to maximizing the satellite ERP by controlling system loss and providing antenna coverage with reasonable polarization characteristics is one step. A second issue is the use of modulation formats with error correction coding that minimize reception requirements for users. For example, HRPT transmissions do not employ error correction coding, and consequently, the required antenna size for reception is relatively large. The processing gain from modulation coding would permit smaller terminal designs desired for tactical use. The satellite design objectives for developers thus should include attention to minimize the burden on users if the goal of effective terminal equipment is to be realized. A third issue is administrative. The RDS DMSP data is presently encrypted providing security obligations that impose unwanted restrictions on users. The need for encryption of low resolution data requires reexamination. NPP will not be encrypted. NPOESS will also be unencrypted unless otherwise directed in times of national emergency. Unencrypted RDS data transmissions would be more attractive to military users and would open the possibility for commercial applications and extension of services to third world nations.

II. Field Terminal Requirements and Design

The generic requirements and design concepts for future tactical field terminals are described. The overall requirements emphasize cost-effective designs, provide ease of operation, and have increased resistance to interference. Cost-effective designs can be achieved by capitalizing on COTS ASIC receiver technology and affordable laptop computer platforms for terminal control, data processing and storage requirements. Thus, one objective is to use recent technology developments to reduce acquisition costs. Terminal designs for effective operation must be portable, rugged, and easily deployed. Integration of antenna and receiver components provides a single package for easy deployment. A single antenna with integrated receivers could be timeshared between RTD, WEFAX, HRPT, and satellite communications. It is envisioned that a single integrated package with the size of a suitcase would meet this requirement and ease transportation, deployment and logistics burdens. Using a low cost antenna treated as an expendable item provides high resolution reception. Interference from other terrestrial sources is a problem with existing designs, and will prove even more troublesome as L- and S-band cellular services increase in the future. Thus, design attention to the filtering distribution and receiver linearity must be addressed in future designs to reduce interference vulnerability.

The future design concepts capitalize on receivers implemented with COTS ASIC technology. The receivers are configured with the RF electronics, i.e., front end filter, low noise amplifier, and downconverter packaged with the feed and the bit synchronizers, error correction decoder, and demodulators in ASIC technology packaged separately. It is believed that a common ASIC receiver package can be developed to serve the different downlinks for meteorological data. This same receiver connected to the appropriate RF front end can be reprogrammed for the data rate and modulation format for the specific downlink being used. In this way, the receiver would have a common design to achieve economies of manufacture, ease of replacement and logistical benefits. The interfaces between the integrated antenna/receiver and a laptop computer would be baseband and DC power. Thus, the field terminal would be comprised of two packages, the antenna/receiver and the laptop computer. This packaging and its interface is also advantageous in applications where the antenna is to be remotely located from the user's laptop terminal. When encryption is used, it is desirable to locate the crypto with the laptop for security protection and thus the interface also requires transferring encrypted and unencrypted data through the baseband interface. With common receiver hardware, the principal distinction in the field terminals for different meteorological downlinks lies with the antennas and RF front ends. Appropriate antenna systems for different readout terminals are described.

A. Low Resolution Users

Typical users in the first class are tactical first-in units that require basic meteorological data to determine near term estimates of prevailing weather and general cloud coverage characteristics. Terminal equipment must be minimal and highly portable. A desire also exists for an "image on the move" capability for moving platforms. Such equipment also has potential commercial applications and capabilities for third word nations. Low resolution data is presently available from the APT and DMSP RDS downlinks.

The VHF APT service and the technology is well developed and cost effective. Typically, a short helix antenna and preamplifier are integrated within a single package to obtain hemispheric coverage without the need for antenna steering. The APT receiver is a simple single card device and in one form can be added to an expansion slot in a PC. The modest cost permits use at a "hobbyist" level. An alternative antenna design has been developed, and was envisioned to be dual band for APT and the UHF RDS service (Ref. 2). However, for the RDS data rate, the link impairments at UHF result in questionable availability for antenna designs without a pointing capability. The VHF portion of this antenna can be used by itself and the design can also house the receiver within a volume comparable to the existing helix antenna. A front end filter can be added to reduce susceptibility to high level out-of-band interference. With the high antenna temperature levels at these frequencies, the sensitivity degradation from the filter loss is minimal. The laptop requirements are very modest for such a system. The data is unencrypted. The design simplicity results in a cost-effective capability that follows the objectives described here.

The DMSP RDS is a second low resolution service. Recently, the electrical feasibility of a terminal concept was demonstrated (Ref. 1). A horn antenna providing a high G/T level from a compact package was developed. A receiver configured from COTS ASIC components was also developed. This terminal design together with in-house-developed display software was recently demonstrated using S-band RDS transmissions from F15. Further development is being pursued to devise a "production-like" model that can be transferred to other organizations for independent evaluations.

A simple positioning system is also being investigated that capitalizes on COTS RV designs to compensate for vehicle motion to obtain an “image on the move” capability.

B. Multi-Sensor/Communication Users

The second user class requires additional capabilities and higher resolution service. Systems with increased portability and ease of assembly and disassembly remain issues, but clearly this user class requires more extensive terminal equipment than low resolution users. Several meteorological satellite downlinks provide high resolution data at the present time and include the RTD service from DMSP, the HRPT service from POES, and the WEFAX service from GOES. These downlinks require antennas having at least a 3 ft aperture size. Future communication objectives, whether VSAT relay or broadcast services, also require about the same size aperture. Likewise, similar aperture sizes will be needed for the LRD downlink in the NPOESS era. Thus, a single antenna system that can be timeshared with the remote sensing satellites when they are in view, and the communication services as required is attractive. Such a single antenna that satisfies multiple mission objectives reduces the amount of required tactical equipment, one objective for future development. The objective here is to reduce the number of antennas that operators are required to deploy and at the same time, permit reception for future fused data from broadcast services. Such an approach is cost effective and reduces amount of hardware to increase system portability. An automated scheduler for such designs could be developed to manage its operation.

An example concept in Fig. 1 illustrates the envisioned antenna design. This figure depicts the antenna in three positions, stowed and at the two extremes of the elevation travel. An offset reflector with a multiple frequency capability is used. The positioner is designed in a collapsible form that would stow into a shipping case. As shown, the design would provide a full 180^{o} travel in elevation angle to minimize “keyhole” limitations for high elevation angle passes of polar satellites. The receiver has separate LNA’s and downconverters for the different bands and an ASIC back end mounted as a “blister” on the back of the reflector. The top of the case, when deployed, provides a platform for the antenna/receiver and could be filled with locally available material to weight it. Loops built into the case sides could be used to lash it down. During transit, the overall system would have the size and form of a large pullman suitcase.

The RF design would include a L-/S-band feed at the prime focus position and feeds for future X-band and EHF communications in a Cassegrain configuration with separate frequency selective surfaces. Such a design provides operation at the multiple frequency bands required in this application. Since broadcast and tactical communications at 20 GHz use opposite polarization senses, design attention to axial ratio performance is required. Program track would be used for the lower frequency polar orbits as is done today. The terminal location can be derived from a GPS receiver that also provides a reference time, and the orientation of the terminal may be obtained from a simple radio compass. A level sensor might also be incorporated to determine any offsets that may limit pointing performance. The communications capability is

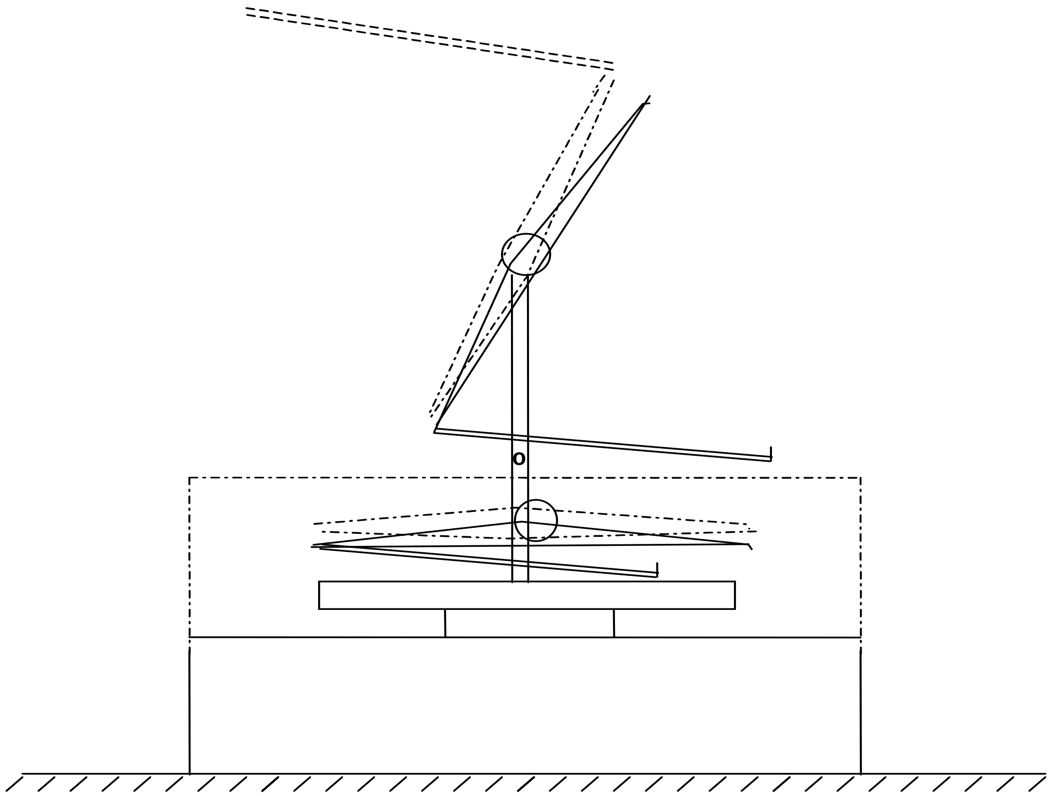

Fig. 1. Multi-Sensor Terminal Concept

envisioned to be limited to geosynchronous orbits, and antenna tracking for these orbits can be assumed to be a nominal program track refined by step track validation. Thus, the need for more complex tracking feed designs is avoided.

C. High Resolution Users

The third user class requires not only the same equipment as the second class but in addition the capability to receive high resolution services from satellites such as GOES for rapid refresh. These existing high resolution downlinks presently require 10 to 12 ft aperture sizes for reception. In the NPP and NPOESS timeframe, antennas of this size are also required to receive X-band HRD downlinks. For NPP and NPOESS operation, a positioner capable of tracking the satellite and a tracking feed design is needed. Users in this class are typically found at hubs, such as the Operational Weather Squadron (OWS) level. The high resolution data can be fully processed to the EDR level, ingested in numerical weather prediction models, and subsets of the data and derived production can be disseminated to field users with limited or no METSAT receipt capability. It is reasonable to anticipate future application of data fusion concepts and the incorporation of local weather observations into the forecasting. Thus, both equipment and training needs are expected to be higher for such capabilities.

This user class has less demanding requirements for equipment portability. For example, pouring a concrete pad to mount the high resolution antennas is not an unreasonable requirement. These larger antenna sizes are also relatively visible targets, and consequently the ability to separate these antennas to remote locations is typically needed. While tactical antennas in this size have been developed, their cost is very high. Therefore, an objective of this design concept is to achieve a significant savings. What is envisioned is capitalizing on existing satellite TV antenna technology whose cost is sufficiently low (< $1K) that the antenna reflector can be treated as an expendable item. Because the high resolution capability lacks the stringent requirements for portability in other terminal designs, some latitude exists in its development. Unlike the other designs, antenna assembly would be required on site. It is envisioned that the disassembled antenna would be shipped in boxes in the same way the antennas are provided to consumers. This approach (Ref. 3) has already been used in Bosnia.

The expendable antenna reflector provides several attractive features. Satellite TV designs, while inexpensive, are relatively rugged and can be assembled without great difficulty. These antennas are designed for use with geosynchronous orbits also used by meteorological satellites and can select satellites over the geosynchronous belt. Typically, these antennas are mounted with a pipe interface in poured concrete, a reasonable requirement for this user class. The reflector is comprised of a set of ribs that are covered by a mesh surface to form the reflector. The feed for C- and Ku-band reception would be replaced by an L-band feed, LNA, and downconverter that would be used with the ASIC receiver components. Because antennas of this size are highly visible, they often have the requirement to be separated in a remote area. Relatively long interfaces can be readily achieved by fiber optics technology. Because these inexpensive antennas are visible targets, damaged antennas whether by ordinance or not can be replaced with another unit. Disassembly of such antennas is also visible to the adversary, and can indicate changing military strategies and locations. Since the antennas are viewed as expendable, simply leaving the reflector behind and assembling another reflector at the next location is envisioned. As appropriate, substituting a commercial S- and/or Ku-band feed after military service would provide local satellite TV services as a public relations advantage.

The high resolution data can be processed at the site and fused with other local data. If sufficient training is provided and effective software is developed, such data fusion may be practical in the future. The alternative is to relay the data to a central processing area; existing services such as DSCS may be appropriate for the relay. Receiving timely updates from the fused data is a principal issue, and therefore a broadcast service such as GBS is envisioned. In this way high resolution data focused and edited for specific regions of interest would be available by users terminals significantly smaller than that required to receive the high resolution data itself.

While a compact RDS design has been demonstrated, additional development is required to implement these concepts. Exploration of the antenna systems for the multi-sensor and high resolution designs (Ref. 4) will be pursued in an SBIR effort that will be under contract shortly. This SBIR effort is managed by the AFRL organization at

Hanscom AFB. The receiver technology is relatively straightforward, but device with long availability and low power consumption require further examination and selection.

III. Summary and Recommendations

This discussion has proposed suggested design options and future development for satellite meteorological data readout. The objectives behind this proposed development include cost effective designs, ease and flexibility of operation, and reduced susceptibility to interference. The commercial utility of these alternative designs also appears to be a positive byproduct. However, it is again emphasized that several factors are needed to realize these objectives:

1. Satellite design attention is needed to deliver adequate signal power levels to allow users to receive data with an minimal amount of equipment and performance
2. Using modern modulation and error correction techniques to reduce the required user resources
3. Reexamining the need to encrypt low resolution data will reduce user burdens and provide a potential avenue for exploitation by commercial and third world users
4. Developing integrated antenna/receiver designs to minimize user transport and deployment requirements will substantially increase user effectiveness
5. Devising and developing effective mission software capable of operation with laptop platforms will minimize unit cost and increase portability.

These factors are particularly important as new designs are devised in the NPOESS era, but are even more relevant today. The ability to provide timely data to users having minimal equipment requirements is a key to the success of future systems.

Acknowledgement

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